Summary

Computer Security Lecture 17

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[1] Based on original lecture notes by David Aspinall

Outline

Programming against security

Techniques for threat analysis

From security evaluation to security management

Revision

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- A **worm** is a program that copies itself from one machine to another. Research began on benign worms for distributed computation (current term: "agents").

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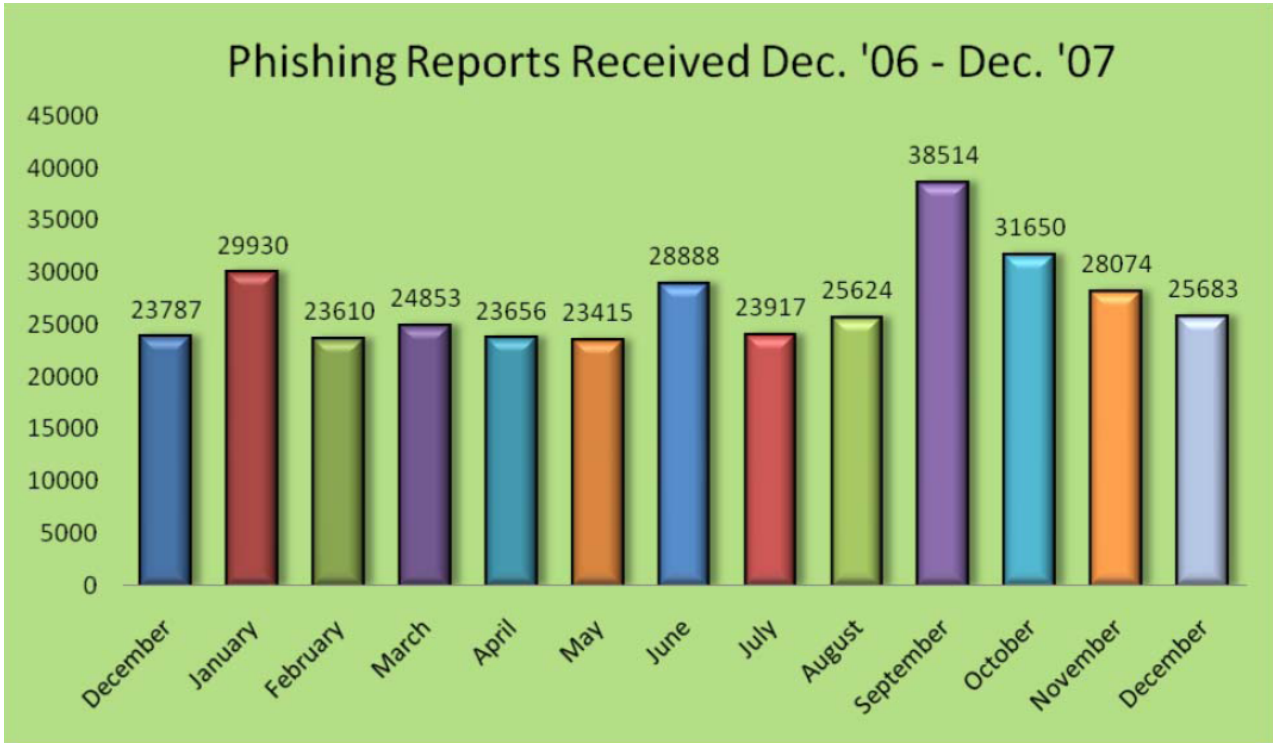
- For more, see `http://www.antiphishing.org/`. Following images are from APWG reports.

Phishing


Phishing Reports Received Dec. '06 - Dec. '07
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
23787
29930
23610
24853
23656
23415
28888
23917
25624
38514
31650
28074
25683
December
January
February
March
April
May
June
July
August
September
October
November
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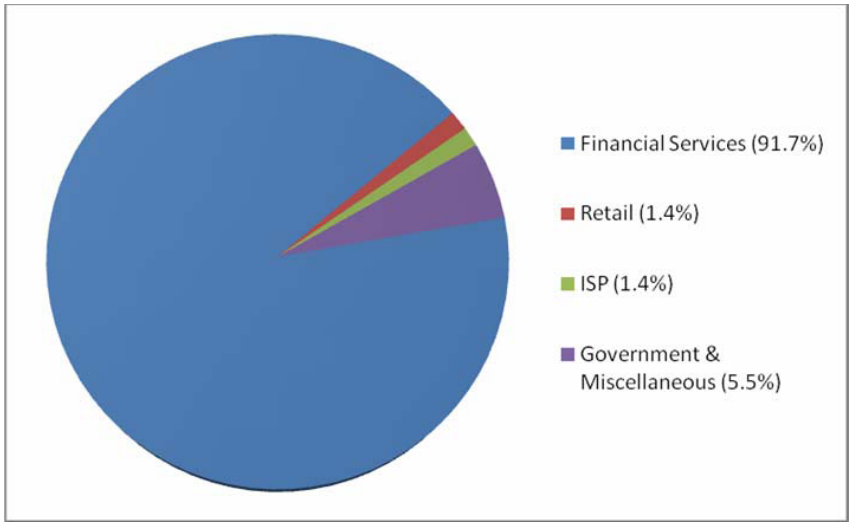
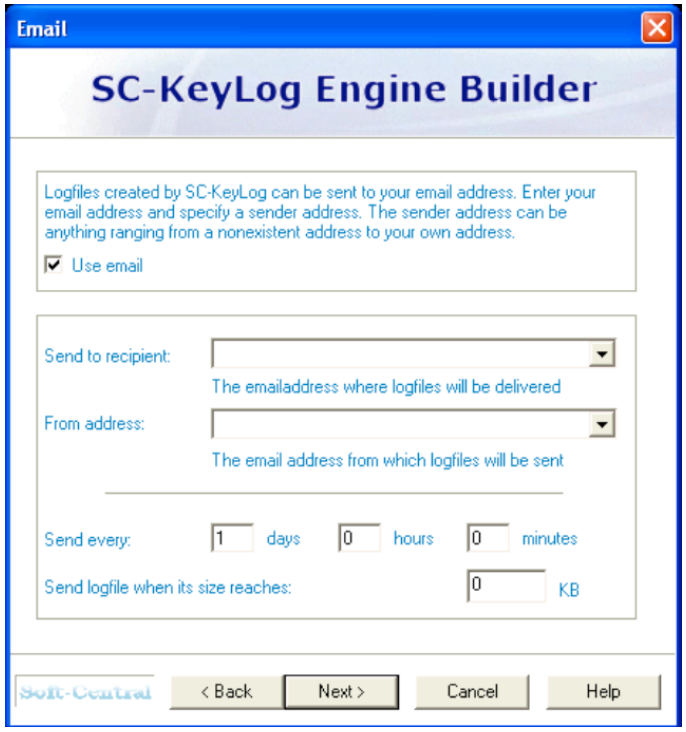
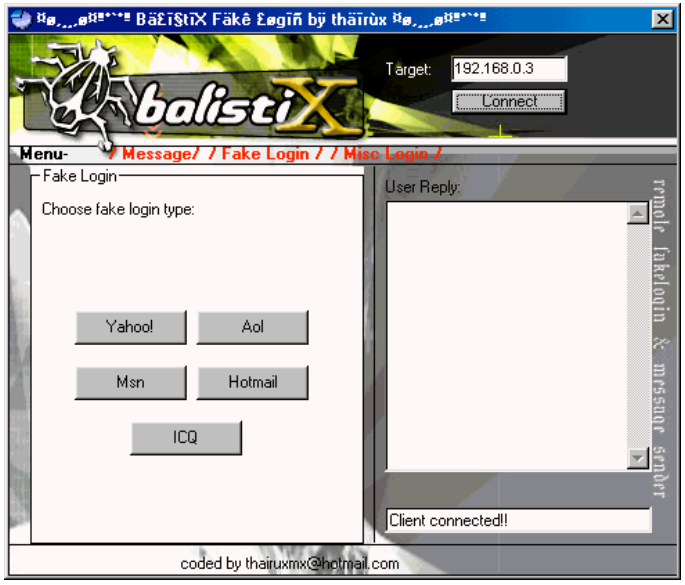
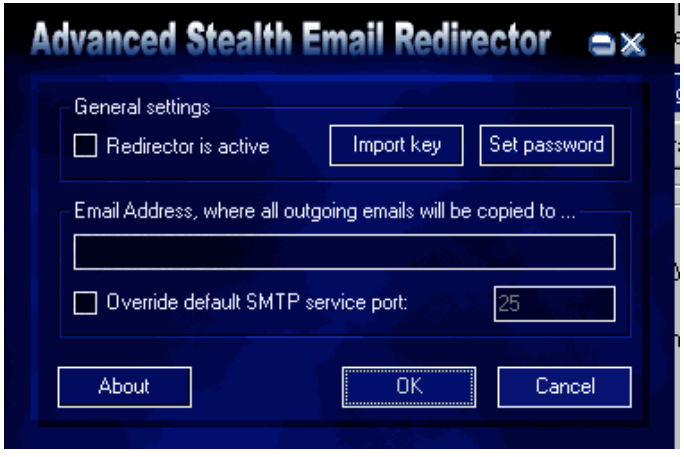

Financial Services (91.7%)
Retail (1.4%)
ISP (1.4%)
Government & Miscellaneous (5.5%)

Building crimeware







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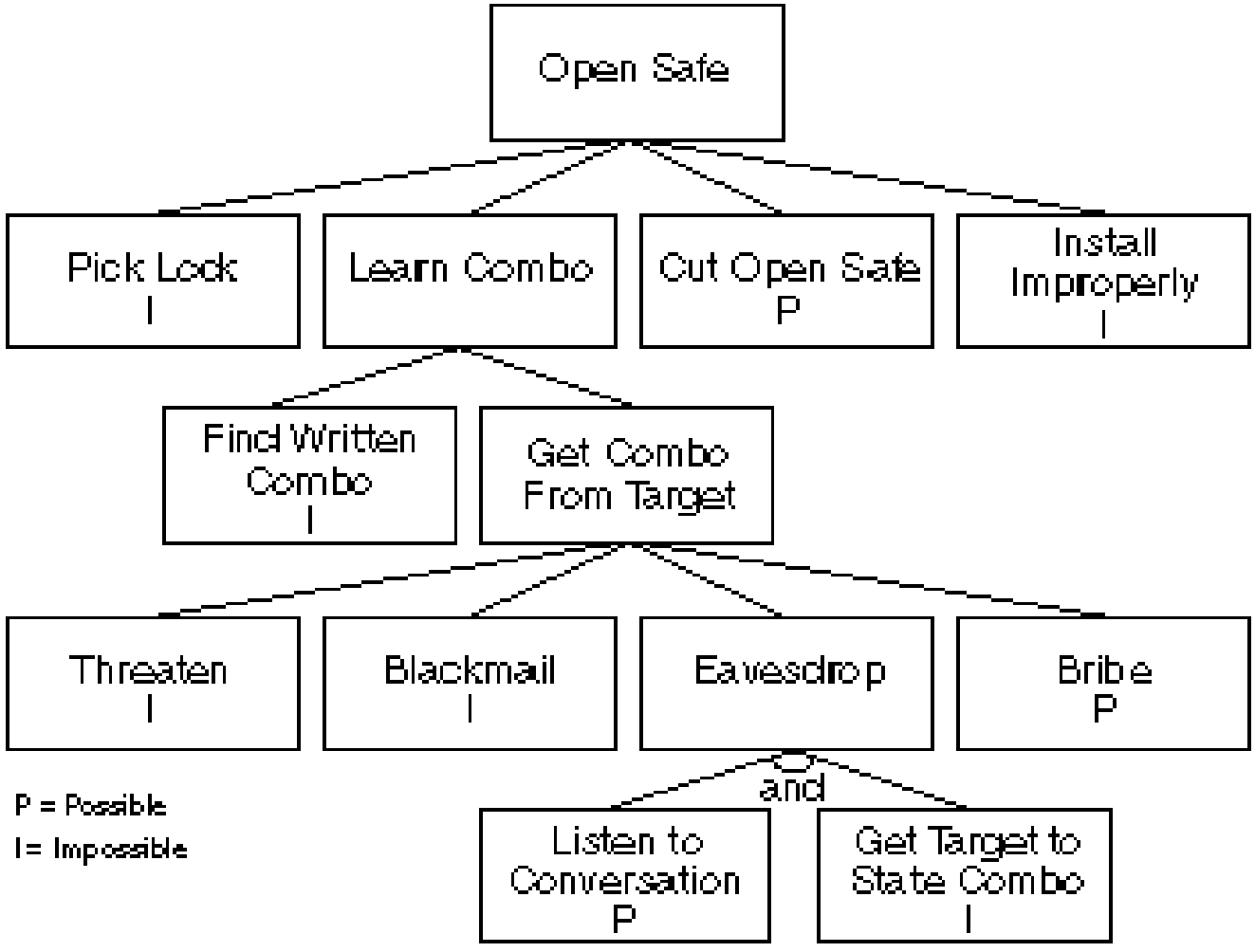
Attack Tree for Safe Cracking [Sch99]



Attack scenarios generated by depth-first tree traversals excluding impossible cases.

Attack Tree for ACME Web server [MEL01]

Access sensitive data from privileged account at ACME

AND 1. Get access to privileged account on web server
- *OR* 1. Exploit buffer overflow vulnerability to access privileged account
  - *AND* 1. Identify executable program on ACME Web server susceptible to buffer overflow vulnerability
    2. Identify code that would provide access . . .
  - 2. Exploit unexpected operator vulnerability to access privileged account
  - *AND* 1. Find executable program on ACME Web server susceptible to vulnerability
    2. Identify (unexpected) operator that permits composing system calls
    3. Identify system call that would provide access to privileged account . . .

2. Scan files for sensitive data

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Elevation of privilege e.g., user illegitimately gains power of root user

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- In terms of risk assessment, Damage and Affected Users are measures of **impact**, reproducibility, exploitability and discoverability are measures of **likelihood**.

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- Achieving compliance with the processes required in the standard is a significant undertaking for an organisation (cf ISO 9000).

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8. **Operations management**: documented procedures; change control; segregation of duties; separation of development and operational facilities; malware controls; backups and logs; network management; media handling; information exchange email, agreements, e-commerce, . . .

Sample of ISO 27001/2 areas, cont’d

9. **Access control**: policy specification; user management; network controls; OS and application controls; monitoring; mobile and teleworking.

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- Mutual authentication with shared keys:

$$\begin{array}{lll} \text{Message 1.} & S \rightarrow A: & N_s \\ \text{Message 2.} & A \rightarrow S: & \{N_s, N_a, S\}_{K_{as}} \\ \text{Message 3.} & S \rightarrow A: & \{N_a, N_s\}_{K_{as}} \end{array}$$

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- Symmetric constructions: stream (one-time pad and LFSR) and block (substitution, permutation, product)

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- Asymmetric ciphers: RSA, Diffie-Hellman, ElGamal

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- In overview: IPsec, DNSSec, SSH, VPNs

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- Particular model: Bell-LaPadula.

Reminder: Secure programming

splitvt, syslog, mount/umount, sendmail, lpr, bind, gethostbyname(), modstat, cron, login, sendmail again, the query CGI script, newgrp, AutoSofts RTS inventory control system, host, talkd, getopt(), sendmail yet again, FreeBSD s crt0.c, WebSite 1.1, rlogin, term, ffbconfig, libX11, passwd/yppasswd/nispasswd, imapd, ipop3d, SuperProbe, lpd, xterm, eject, lpd again, host, mount, the NLS library, xlock, libXt and further X11R6 libraries, talkd, fdformat, eject, elm, cxterm, ps, fbconfig, metamail, dtterm, df, an entire range of SGI programs, ps again, chkey, libX11, suidperl, libXt again, lquerylv, getopt() again, dtaction, at, libDtSvc, eeprom, lpr yet again, smbmount, xlock yet again, MH-6.83, NIS+, ordist, xlock again, ps again, bash, rdist, login/scheme, libX11 again, sendmail for Windows NT, wm, wwwcount, tgetent(), xdat, termcap, portmir, writesrv, rcp, opengroup, telnetd, rlogin, MSIE, eject, df, statd, at again, rlogin again, rsh, ping, traceroute, Cisco 7xx routers, xscreensaver, passwd, deliver, cidentd, Xserver, the Yapp conferencing server, multiple problems in the Windows95/NT NTFTP client, the Windows War and Serv-U FTP daemon, the Linux dynamic linker, filter (part of elm-2.4), the IMail POP3 server for NT, pset, rpc.nisd, Samba server, ufsrestore, DCE secd, pine, dslip, Real Player, SLMail, socks5, CSM Proxy, imapd (again), Outlook Express, Netscape Mail, mutt, MSIE, Lotus Notes, MSIE again, libauth, login, iwsh, permissions, unfsd, Minicom, nslookup, zpop, dig, WebCam32, smbclient, compress, elvis, lha, bash, jidentd, Tooltalk, ttdbserver, dbadmin, zgv, mountd, pcnfs, Novell Groupwise, mscreen, xterm, Xaw library, Cisco IOS, mutt again, ospf_monitor, sdtcm_convert, Netscape (all versions), mpg123, Xprt, klogd, catdoc, junkbuster, SerialPOP, and rdist

- This is a year’s worth of (reported) buffer overflow vulnerabilities (2000/1).

References

[Sch99] Bruce Schneier. Attack trees.

Dr Dobb's Journal, December 1999. Available at `http://www.schneier.com/paper-attacktrees-ddj-ft.html`.

Information technology — code of practice for information security management, December 2000.

Standard: ISO/IEC 17799 and BSI BS7799.

[MEL01] Andrew P. Moore, Robert J. Ellison, and Richard C. Linger. Attack modeling for information security and survivability.

Technical Report CMU/SEI-2001-TN-001, Software Engineering Institute, Carnegie Mellon University, 2001.

[HL03] M. Howard and D. LeBlanc. *Writing Secure Code*.

Microsoft Press, second edition, 2003.

Recommended Reading

Schneier's attack tree article. Chapter 1 of Gollmann's textbook *Computer Security*.